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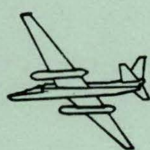

FINAL REPORT

LOUISIANA MIDCYCLE TIMBER INVENTORY PILOT TEST

FEASIBILITY STUDY

September 1981

USDA Forest Service
Houston, Texas

NATIONWIDE FORESTRY APPLICATIONS PROGRAM

ADVANCED REMOTE SENSING TECHNOLOGY DEVELOPMENT

FINAL REPORT

LOUISIANA MIDCYCLE TIMBER INVENTORY PILOT TEST

-- FEASIBILITY STUDY --

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16. Abstract

A survey technology which uses high altitude panoramic photography in conjunction with two-stage sampling was developed and tested in three forest regions of Louisiana during the 1980 midcycle timber inventory update. It was found that of the 15.6 million acres in the survey area, 10.7 million acres are forested - a reduction of less than 1 percent over the 1974 estimate. On the other hand, the growing stock volume increased by 11 percent from 12.1 billion cubic feet in 1974 to 13.4 billion cubic feet in 1980.

The results obtained in this first application of high altitude panoramic photography and two-stage survey technology to a midcycle inventory produced acceptable level of precision. Problems encountered in data gathering and analysis during this Louisiana pilot test will serve as guideposts in making the survey technology more efficient and accurate for the large scale test phase of the Timber Inventory Project to be implemented in Oklahoma.

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1. INTRODUCTION

The Southern Forest Experiment Station (SO) of the U.S. Department of Agriculture (USDA) Forest Service is responsible for the assessment of forest resources in several southern states (Texas, Oklahoma, Arkansas, Louisiana, Mississippi, Kentucky, Tennessee, and Alabama). Intensive surveys of these resources are conducted approximately every ten years. User demands for more frequent estimates have led the Station to add midcycle (5 year) inventory updates to its regular surveys.

Going one step further than merely satisfying the need for more frequent inventories, the Southern Station sought a new and promising survey technology, one that uses high altitude aerial photography, to maximize the efficiency of midcycle surveys.

Recognizing the extensive experience and leadership of the Nationwide Forestry Applications (NFA) Program in the development and application of high altitude panoramic photography for resource assessments (Dillman et al 1980, Hinkle et al 1980, Weber 1977), the Southern Forest Experiment Station requested NFA Program's assistance with the 1980 timber inventory update for the State of Louisiana. The NFA Program extended technical assistance to the Station through the Timber Inventory Project (TIP).

The objective of TIP was to develop, implement, and evaluate an efficient survey technology which uses high altitude panoramic

photography for updating forest land base and timber volume statistics in a midcycle inventory (Eav and Hinkle 1980).

To accomplish its objectives, the project was organized into three phases: (1) point transfer accuracy test, (2) feasibility study, and (3) large scale test.

The first phase of TIP was designed to determine the accuracy with which forest survey plot locations can be transferred from 1:20,000 scale black-and-white photographs to 1:30,000 nadir scale color infrared optical bar photography (Ward et al 1980). In the second phase, procedures for photointerpretation, regeneration photointerpretation key, and preliminary design of the new survey technology were developed and tested in pilot scale. The large scale test phase will attempt to develop and implement an optimum midcycle survey design based on the results obtained from the first two phases. This third phase will be carried out in Oklahoma.

This report discusses the development of procedures and the results obtained in the Louisiana midcycle timber inventory pilot test. The Photointerpretation Key for Pine Regeneration Analysis (Eav et al 1981) and this final report document the second phase of the Timber Inventory Project.

2. OBJECTIVES

The specific objectives of the Louisiana Midcycle Timber Inventory project are to:

- Develop and test procedures for photointerpretation of land cover classes at Renewable Resource Evaluation unit's sample plots
- Develop a photointerpretation key for analysis of regeneration areas on high altitude color infrared panoramic photography
- Develop and test a preliminary sampling design for timber inventory update
- Assist the Southern Forest Experiment Station with the 1980 timber inventory update for the State of Louisiana.

3. STUDY AREA

The study area covers three (Northwest, Northeast, and Southeast) of the five forest regions of Louisiana (Figure 1) with a total land area of 15.6 million acres.

This area encompasses the majority of the commercial timber lands of Louisiana. According to a 1974 survey (Earles 1975), it contains 10.8 million acres of forest lands of which 8.5 million acres are on pine site (97 percent of the State's total pine site). It was also reported to contain 12.1 billion cubic feet of growing stock volume.

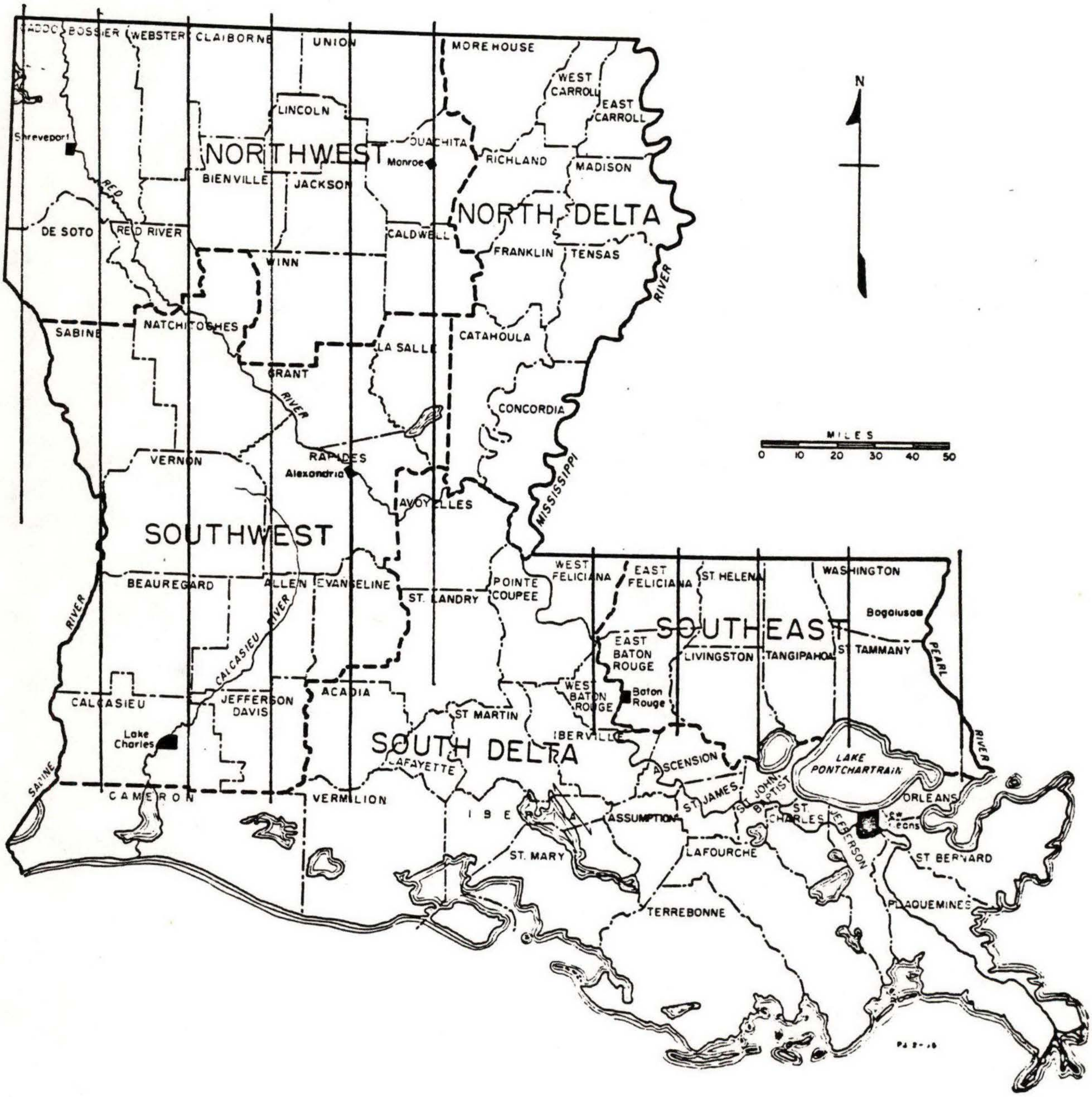

Figure 1.-- Louisiana Midcycle Timber Inventory areas with flight lines for high altitude panoramic photography

4. MATERIALS AND METHODS

The essential materials for the project are plot records, plot summary statistics, high altitude color infrared panoramic photography, and photointerpretation equipment.

4.1 PLOT RECORDS

Plot records consist of:

a. County maps at a scale of 1:63,360 (1 inch to a mile) used to carry information on the approximate locations of the permanent survey plots

b. Black-and-white aerial photographs which contain plot location and land use information.

4.2 PLOT SUMMARY STATISTICS

Plot growing stock volume from the previous survey was used to determine the probability of selection of sample plots for ground measurements and for computing changes.

4.3 AERIAL PHOTOGRAPHY

A National Aeronautics and Space Administration Ames Research Center (NASA/ARC) U-2C aircraft operating under a cost-reimbursable agreement with the NFA Program collected high altitude color infrared panoramic photography (Missions 80-014 and 80-015) on March 4 and 5, 1980. The photography was taken at 65,000 feet above mean sea level with 50 percent forward lap at nadir using

an Optical Bar Panoramic Camera, Itek KA-80A. This camera system provides high resolution stereoscopic ground coverage from high altitude. With the 24-inch lens, photography has a nadir scale of 1:32,500 assuming that the terrain is a sea level datum plane. The description of the camera system and the panoramic geometry of the photography can be found in Hinkle (1981).

The film used was Kodak High Definition Ektachrome Infrared (SO-131). Processing was done in accordance with NASA Photographic Processing Laboratory specifications.

As shown in figure 1, 11 flight lines were required to cover the survey area. The flight missions produced 1261 frames or approximately 5500 feet of aerial photography.

5. PROCEDURES

5.1 PHOTOINTERPRETATION

The photointerpretation task consisted of two major activities: (1) transfer of permanent sample plot locations from plot records onto high altitude panoramic (OBC) photography, and (2) identification of land cover/use class on each plot location. A total of 2716 plot locations were transferred and photointerpreted. The procedures used to accomplish this task are as follows:

a. Index high altitude panoramic film - Plot flight lines on a mosaic of eleven 1:250,000 USGS topographic maps.

b. Transfer plots - Transfer approximate locations of plot centers to the 1:250,000 flight line map with a 1:250,000 scale 3-mile grid overlay.

c. Identify start and stop of each roll of film - Eliminate sidelap between passes by assigning overlap plots to the closer nadir. Assign plot numbers to each roll of film.

d. Arrange photography - Arrange black-and-white resource photos by area covered by each roll of film.

e. Interpret photography - At the beginning of each roll of film, use the corresponding resource photos and the Parish plot map to:

   - Identify the 4-5 resource photos and respective renewable resource evaluation plots falling on the first panoramic frame

- Locate the general plot area on the OBC film using Parish plot map
- Visually transfer plot centers from resource photos onto the OBC frame and mark/label plot with grease pencil
- Identify land use within the immediate plot area (approximately one acre) and fill in classification sheet with the following codes:
    - 10 - forested
    - 18 - pine regeneration
    - 19 - recent clear cut (no regeneration visible)
    - 60 - permanent non-forest
    - 61 - cropland/pasture
    - 90 - water

5.2 SAMPLING FOR TIMBER VOLUME

Subsampling was based on the existing permanent sample network consisting of systematic sample locations at the intersection of a 3-mile square grid. Subsample units were selected with probability proportional to size (PPS). This sampling design has been shown to be precise, unbiased, and cost effective for mid-cycle timber surveys (Scott, 1979).

A computer program developed by Stage (1971) was used to sort plots based on 1974 growing stock volume into ascending order and to select a 10 percent sample (180 plots). A probability

weight determined on the basis of the 1974 total growing stock volume at the last survey was assigned to each sample. Field crews were dispatched to the selected sample plots to perform measurements as prescribed in the Forest Resources Inventory Work Plan (Southern Forest Experiment Station 1980). Ten points were sampled at each selected plot location using a 37.5 factor prism to select live trees 5.0 inches d.b.h. and larger (see Figure 2).

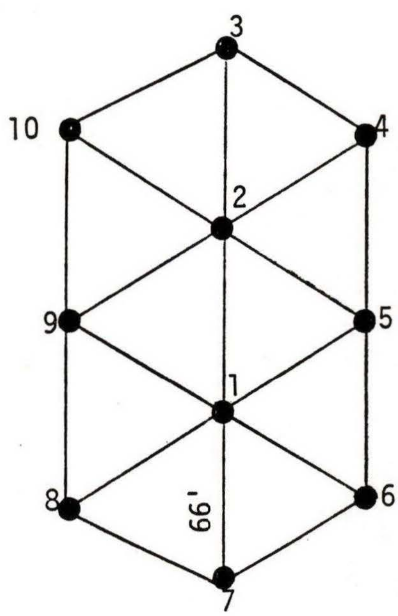

Figure 2.-- Ten-Point Cluster (plot center is at point 1)

6. ANALYSIS

6.1 FOREST AREA

Personnel at the Renewable Resources Evaluation Unit (SO) reviewed the classification sheets provided by Lockheed. The new classification was compared to the detailed plot information from previous inventory. Misclassified survey plots were reinterpreted and/or ground checked for verification.

Once the verification procedures were completed, the land use classification was assumed to be 100 percent correct and the total area of commercial forest land were then computed using the formula:

$$\hat{A}_F = A\ \hat{p}$$

where $\hat{A}_F$ = estimate of total commercial forest land area

A = total land area

$\hat{p}$ = proportion of sample plots in commercial forest land.

The variance of $\hat{A}_F$ was estimated by:

$$V(\hat{A}_F) = A^2 \frac{\hat{p}\ \hat{q}}{(n' - 1)}$$

where $\hat{q} = 1 - \hat{p}$

n' = number of photointerpreted survey plots.

6.2 TIMBER VOLUME

Measurements obtained by field crews at the selected subsample plots were processed at the SO computer facilities in New Orleans, Louisiana. The total growing stock volume for the study area was computed by:

$$\hat{Y} = N[\bar{y} + b(x - \bar{x})]$$

where $\hat{Y}$ = estimate of total volume

N = total number of possible sample plots in commercial forest area

$\bar{y}$ = mean 1980 volume for subsample plots

b = regression coefficient (slope)

x = mean 1974 volume for large-sample plots

$\bar{x}$ = mean 1974 volume for subsample plots

The variance of estimate was computed using large sample estimators of variance for linear regression estimator:

$$V(\hat{Y}) = \frac{N^2}{n(n-2)} \Sigma[(y_i - \bar{y}) -b(x_i - \bar{x})]^2$$

where $V(\hat{Y})$ = variance of the estimate

n = number of plots in the subsample

y_i = 1980 volume in plot i

x_i = 1974 volume in plot i

7. RESULTS

The total commercial forest area for the 31 counties included in the survey area was estimated to be 10.7 million acres with a sampling error of 0.7 percent. This represents a small overall decline (1 percent) in forested land as compared to 10.8 million acres reported in the 1974 survey (Table 1).

The total growing stock volume was estimated at 13,412 million cubic feet with an associated estimation error of 778 million cubic feet or 5.8 percent. This volume represents an 11 percent increase (1,297 million cubic feet) over the 1974 growing stock volume of 12,115 million cubic feet (Table 1).

The results obtained in this survey update confirm the continued trend of intensification of forest management in Louisiana. While some forest acreages were lost due to land clearing for crops and residential-industrial needs, the increase in timber volume per acre in the remaining commercial lands more than made up for the loss. In fact, this survey shows a dramatic increase of 11 percent in timber supply in six years between 1974 and 1980 in the survey area.

Table 1.-- COMMERCIAL FOREST LAND AND GROWING STOCK IN 1980 AND CHANGE SINCE 1974

Resource Region	Commercial Forest		Growing Stock	
	Area	Change	Volume	Change
	Thousand acre	Percent	Million cu. ft.	Percent
Northwest	4444.4	-	5282.8	1
Southwest	4573.2	1	5799.7	16
Southeast	1679.3	-6	2330.1	21
Total	10,696.9 ±74.9* (0.7%)	-1	13,412.6 ±643.8* (4.8%)	11

*1 standard error of estimate

8. DISCUSSION

This feasibility test of a new survey technology, using high altitude panoramic photography with two-stage sampling in a midcycle inventory update, was designed specifically to ferret out and determine the range of problems that might arise in a large scale demonstration of such a technology. Indeed, several problems of varying magnitude were discovered in this test.

In this section, the problems encountered in data gathering and analysis of the 1980 Louisiana midcycle inventory update with their implications on the results obtained are delineated.

Use of regression estimates with PPS. - In this survey, subsample plots were selected with probability proportional to size (PPS), while regression estimators were used to arrive at the growing stock volume and its variance. Using regression estimators instead of PPS estimators may have exposed the estimates of growing stock volume to some bias. However, the Renewable Resource Evaluation Unit (SO) judged that more reliable detailed parish-wide update tables were achieved by using regression rather than PPS estimators. Furthermore, the bias associated with regression estimators that may exist can be expected to be minimal as a result of large sample size.

Exclusion of in-grown plots from sampling base. - It is also possible that exclusion of in-grown plots (plots attaining measurable timber volume since last survey) from the sampling base may have resulted in underestimation of the growing stock volume. While the contribution of in-grown plots to total timber volume may be negligible, identification of such plots through aerial photography can reduce, if not eliminate, exclusion of in-grown plots as a potential source of underestimation of inventory updates.

Access to plot historical data. - Available information indicates that accuracy of the commercial forest area estimates could be improved through a reduction of photointerpretation errors. For instance, it is reasonable to believe that greater access to plot historical data would have yielded less misclassified plots. In cases where misclassification was caused by plot centers falling between two land use classes, sketches made by the 1974 survey crews, were they available, could provide valuable input to the photointerpreters. Field notes from previous inventory would have been useful in the identification of pasture lands with tree cover (sometimes erroneously classified as commercial land in this survey). However, it would be well to recall at this point that less than 1 percent of sample plots were misclassified.

Screening out clear cut plots with photointerpretation results. - The present survey could have been made more efficient by using the results of photointerpretation to screen out recently clear

cut plots from being selected for field measurements. However, due to late project start and the rigid schedule of field crews, selection of sample plots for field measurements had to be done before photointerpretation was completed. Thus, forested plots which had been cut since 1974 were included in the sampling base and eleven of these plots were selected for field measurements. Field crews expended a lot of time traveling to these plots only to find there were no standing trees to measure.

Identification of selectively cut/thinned plots. - The photo-interpreters did not attempt to identify survey plots which had been subject to selective cutting or thinning treatment. Had these been identified and the value of auxiliary variable adjusted properly, the estimation error for total growing stock volume would decrease.

To the extent that the problems discussed have impact on the accuracy and efficiency of the inventory, it is necessary to anticipate and recognize these problems when they occur in future applications of this newly-developed survey technology.

9. CONCLUSIONS AND RECOMMENDATIONS

Results strongly suggest that the survey technology presented in this report can be a viable alternative to conventional survey methods. In its first-time application, the inventory technology presented, although less than perfect, produced encouraging results and acceptable level of precision.

As pointed out in the previous section, the problems encountered in this survey can be minimized with careful planning. Consequently, in order to achieve the most accurate and efficient results during the next phase of the Timber Inventory Project planned for Oklahoma, the following steps will be undertaken:

1. Make all detailed historical plot information available to photointerpreters in order to reduce land use classification error.

2. Minimize estimation error and bias by using photointerpretation results in combination with past plot volume to assign probabilities of selection of plots for field measurements.

3. Incorporate in-grown plots, especially pine regeneration plots entering 5 inch DBH class, into the sampling base using the Photointerpretation Key for Pine Regeneration Analysis (Eav et al 1981) to identify these plots.

In addition, as our photointerpreters become more familiar with timber inventory processes and our catalog of high altitude photography for different timber volume levels reaches adequacy (after completion of the Oklahoma project), a method for deriving estimates of timber volume directly from this type of photography should be developed.

For refining the methodology and data analysis procedures of the survey technology, it would be worthwhile, if there is opportunity, to test several promising techniques such as "model-based" and "stratified random sampling with combined regression estimators" which were shown to be efficient in other applications (Schreuder and Lund 1981). The test could be conducted in a future midcycle inventory update project or in a simulation study (also known as Monte Carlo method) and results from the test could be used to compare with those obtained with two-stage pps sampling.

In summary, the survey technology developed for the midcycle timber inventory update in Louisiana, despite the problems encountered, has been demonstrated to produce results comparable with conventional survey methods. If made more efficient and accurate, it promises to be a new tool in the inventory process that can be used with confidence.

10. REFERENCES

1. Dillman, R. D., S. S. Chu, B. B. Eav, and J. C. Prill. 1980. A Pilot Test of High Altitude Optical Bar Camera Photography to Estimte Annual Mortality of Ponderosa Pine Caused by the Mountain Pine Beetle in Colorado. USDA Forest Service, Nationwide Forestry Applications Program, Houston, Texas, LEMSCO-14308.

2. Eav, B. B., C. A. Clark, R. E. Hinkle, and J. C. Prill. 1981. Photointerpretation Key for Pine Regeneration Analysis. USDA Forest Service, Nationwide Forestry Applications Program, Houston, Texas, LEMSCO-15973.

3. Eav, B. B. and R. E. Hinkle. 1980. Timber Inventory Project: Study Plan. Lockheed Engineering and Management Services Company, Inc., Houston, Texas.

4. Hinkle, R. E. (ed.). 1981. High Altitude Imagery User's Guide. USDA Forest Service, Nationwide Forestry Applications Program, Houston, Texas, LEMSCO-16312.

5. Hinkle, R. E., B. B. Eav, J. C. Prill, T. E. Johnson, and R. D. Dillman. 1980. Mount St. Helens Quick Response Damage Assessment Final Report. USDA Forest Service, Nationwide Forestry Applications Program, Houston, Texas, LEMSCO-15320.

6. Schreuder, H. T. and H. G. Lund. 1981. Improved Estimates Through Sample Selection and Estimation. Resources Evaluation Newsletter, Resources Evaluation Techniques Program, USDA Forest Service, Fort Collins, Colorado.

7. Scott, C. T. 1979. Midcycle Updating: Some Practical Suggestions. Proc. Forest Resources Inventory Workshop, Colorado State University, Fort Collins. Colorado, pp. 362-370.

8. Southern Forest Experiment Station. 1980. Forest Resources Inventory Work Plan. USDA Forest Service, New Orleans, Louisiana.

9. Stage, A. R. 1971. Sampling with Probability Proportional to Size from a Sorted List. USDA Forest Service Research Paper INT-88, 16pp.

10. Ward, J. F., B. B. Eav, and R. E. Hinkle. 1980. Photographic Technology Development Project: Point Transfer Accuracy Test. USDA Forest Service, Nationwide Forestry Applications Program, Houston, Texas, LEMSCO-15690.

11. Weber, F. P. (ed.). 1977. Western Dead Timber Pilot Study (Phase II): Final Report. USDA Forest Service, Nationwide Forestry Applications Program, Houston, Texas.